

The Population Consequences of Disturbance Model Application to North Atlantic Right Whales (*Eubalaena glacialis*)

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Award Number: N000141210389
<http://tinyurl.com/RightWhaleResearch>
<http://tinyurl.com/RightWhaleConservationMedicine>

LONG-TERM GOALS

Anthropogenic noise is known to cause both behavioral and physiological changes in marine mammals, but the potential for long-term population effects is not known. The Population Consequences of Acoustic Disturbance (PCAD) model (NRC 2005) provided a framework to trace the effects of acoustic disturbance through the life history of a marine mammal to its population status. Recent developments in the PCAD working group have led to modified analyses (now defined as PCOD – Population Consequences Of Disturbance) designed to determine if the effects of *any* disturbance can be traced from individuals to the population by way of changes in either behavior or physiology (see Figure 1). In North Atlantic right whales (*Eubalaena glacialis*), extensive data on health and body condition, anthropogenic impacts, and individual life history exists. The primary goal of this study is to model visual observations of health, human impacts, and whale locations to estimates of true underlying condition and individual level survival for right whales. A secondary goal is to develop approaches for modeling fecundity. Finally, a workshop to be held in January of 2013 will explore the feasibility of incorporating acoustics, prey variability, and the spatial characteristics of human activities into the PCOD model.

Report Documentation Page

Form Approved
OMB No. 0704-0188

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1. REPORT DATE 2012		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE The Population Consequences of Disturbance Model Application to North Atlantic Right Whales (<i>Eubalaena glacialis</i>)				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) New England Aquarium Central Wharf Boston, MA 02110				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES The original document contains color images.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT SAR	18. NUMBER OF PAGES 7	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

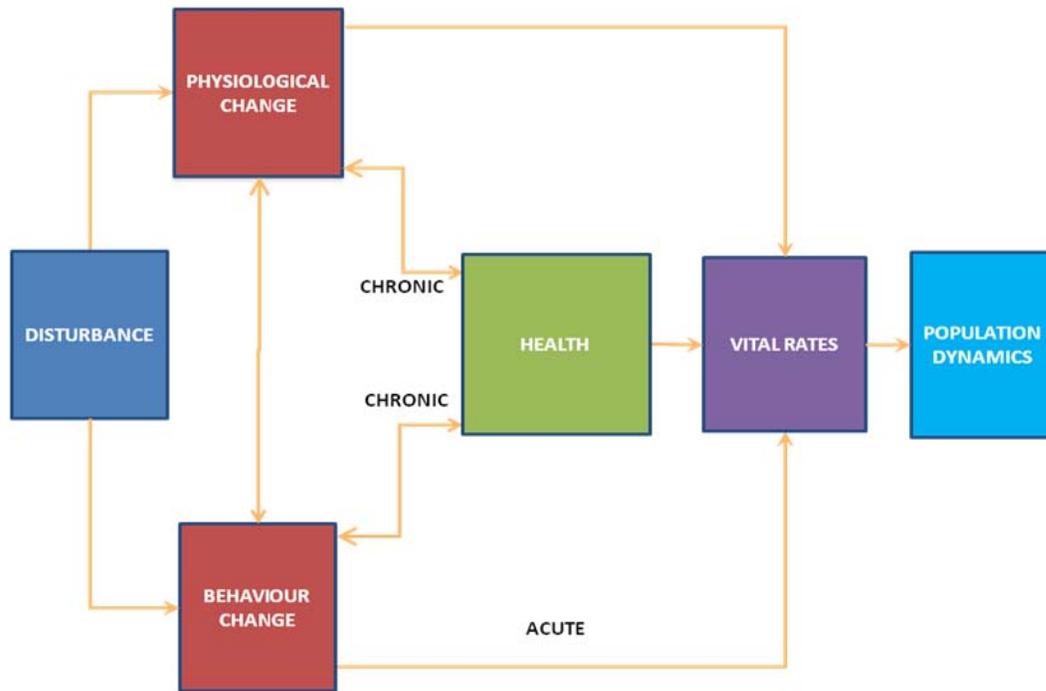


Figure 1. Modified model of population consequences of disturbance (PCOD) (Thomas et al. 2011).

OBJECTIVES

The objectives for this study are to: 1) develop a Hierarchical Bayesian Model to assess right whale biology, 2) assess the effects of health indicators on reproduction and mortality in right whales, and 3) assess the effects of fishing gear entanglements and sub-lethal shipstrikes on reproduction and mortality in right whales. The immediate objective for 2012 was to complete the development of the appropriate model, and to start incorporating the data from entanglements and ship strikes.

APPROACH

At the core of the Bayesian model are one observation model and two process models (Figure 2). The observation model links photographic evidence of health condition to the first process model; this process model provides inference on how health changes over time. Every photographed sighting of the whales contains location information. In the second process model, we assimilate the location information together with informed priors on movement to estimate location and transition probabilities between locations. Finally, estimates of the current states (health and location) inform individual survival. Our team includes Scott Kraus, New England Aquarium (right whale biology), Rob Schick (modeling) Centre for Research into Ecological and Environmental Modeling, University of St. Andrews, Scotland, Amy Knowlton (entanglement and ship strike assessments) and Rosalind Rolland, New England Aquarium (mammalian physiology, health assessments).

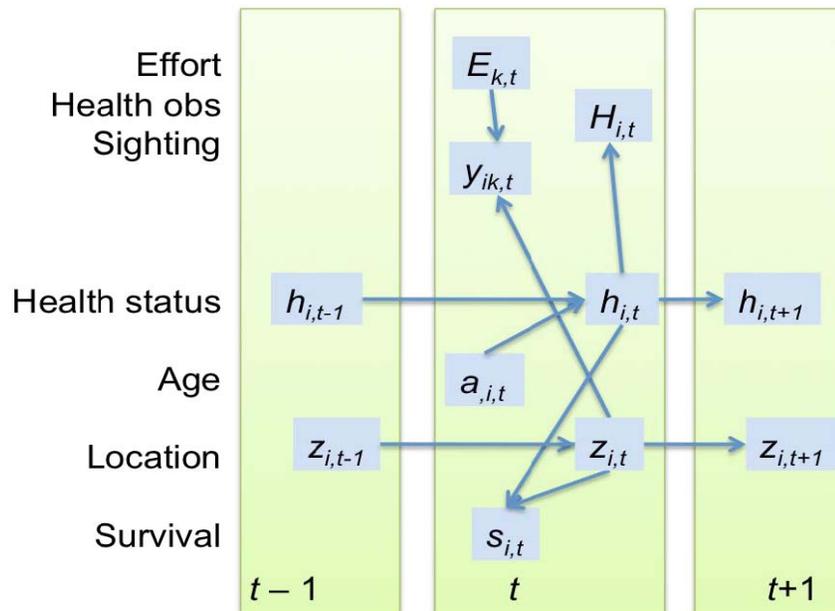


Figure 2. Graphical model depicting the main inferential elements of the right whale model. The top 3 gray boxes indicate the data models: effort comes from the SPUE generated by Dr. Robert Kenney at URI, and sightings and health (including human impacts) observations come from the photographic catalog of individual right whales at the New England Aquarium. The model contains separate process models for health status and location. Survival depends on health and location of individuals. Health status integrates both natural and anthropogenic disturbances that alter the status of a whale, including calving, age-related health, body and skin condition, entanglement events, or sub-lethal vessel strikes.

WORK COMPLETED

Compilation of the right whale entanglement data is completed and vessel strike scarring data is nearly complete. For the initial modeling work, all right whale sightings data collected from 1980 through 2009 were provided to Dr. Rob Schick. In addition, detailed information was provided on all entanglement scarring events detected during this interval. This dataset represents 1,032 unique entanglement interactions involving 519 individual right whales. Each interaction includes the last date when no entanglement scarring was present and the first date when evidence of entanglement was first detected, representing the timeframe within which the entanglement must have occurred. In addition, entanglement severity was classified for the model (minor, moderate, and severe) based on the nature and depth of the wounds (Knowlton et al., in press). Finally, for the subset of cases where fishing gear was still attached to a whale, we calculated the minimum and maximum duration of time the whale was seen carrying gear.

Meetings were held in May of 2012 between the PI's to review the current state of the modeling activity, gather necessary feedback and input from the right whale researchers, and incorporate these changes back into the model. These included:

- a. reviewed modeling progress by examining detailed health time series of individual whales that are well known by NEAQ researchers

- b. discussed specifics of the entanglement and ship scarring data
- c. discussed limits on magnitude of health change within specific timeframes
- d. reviewed detailed priors on movement between and among different geographic regions
- e. reviewed how body fat and skin condition represent the underlying health of the whale
- f. reviewed how calving status represents the underlying health of the whale
- g. reviewed how survival should change for whales that are not seen over a period of years

For example, we reviewed the initial model outputs that were carried out for whales coded as “Very Thin” in the visual health assessment data. The model incorporated sightings, calving events, body condition, skin condition, and entanglement scarring to give an indication of health and survival over time. We compared the model outputs to the known sighting information of the given individual post-2009 to see if the model reflected the sightings data. This comparison allowed for modifications to the model to better reflect the subsequent sightings data. R. Schick incorporated all the information the discussion produced, and a revised output was provided in September 2012 and is presently under review.

The final data to be integrated into the model is the vessel strike data. Similar to the entanglement data procedure, all right whales with evidence of propeller cuts or gashes from a vessel strike have been coded with timeframe and severity levels. A total of 45 cases of right whales that bear evidence of a vessel strike and were seen alive after the strike have been incorporated into the database. A final review of wound severity is being carried out and will be completed and provided to R. Schick by the end of September 2012.

RESULTS

We are now running production runs of the model that will produce three initial manuscripts. The first one, in preparation, provides an overview of the model, and its outputs. The second one will focus on the entanglement and prop-scarring data. The goal of this manuscript is to quantify the impacts of both entanglement and sub-lethal interaction with ships on right whale health. The third manuscript will focus on the health of individuals and the population as a whole.

One of the biggest changes we have made to the model was to introduce an informed survival process as a function of time since last sighting. Approximately 95% of right whales are seen within a 3 year period (Hamilton pers. comm., 2011). Accordingly we made a change to the model, which makes it less likely for the whale to have survived as time since its last sighting increases. The effect of this change can be seen in Figures 1 and 2. Both of these whales were observed in poor body condition, i.e. very thin. The first whale was known to die so the estimates of uncertainty around health do not vary widely (Figure 1). In contrast, the second whale was presumed dead, but not observed (confirmed) dead. After the last sighting, the estimates of health increased slightly (owing to a positive β parameter for health at $t-1$) but then declined to 0. Because we lack observational data, the uncertainty around the estimate of health after the last sighting is quite broad as it declines toward 0 (Figure 2).

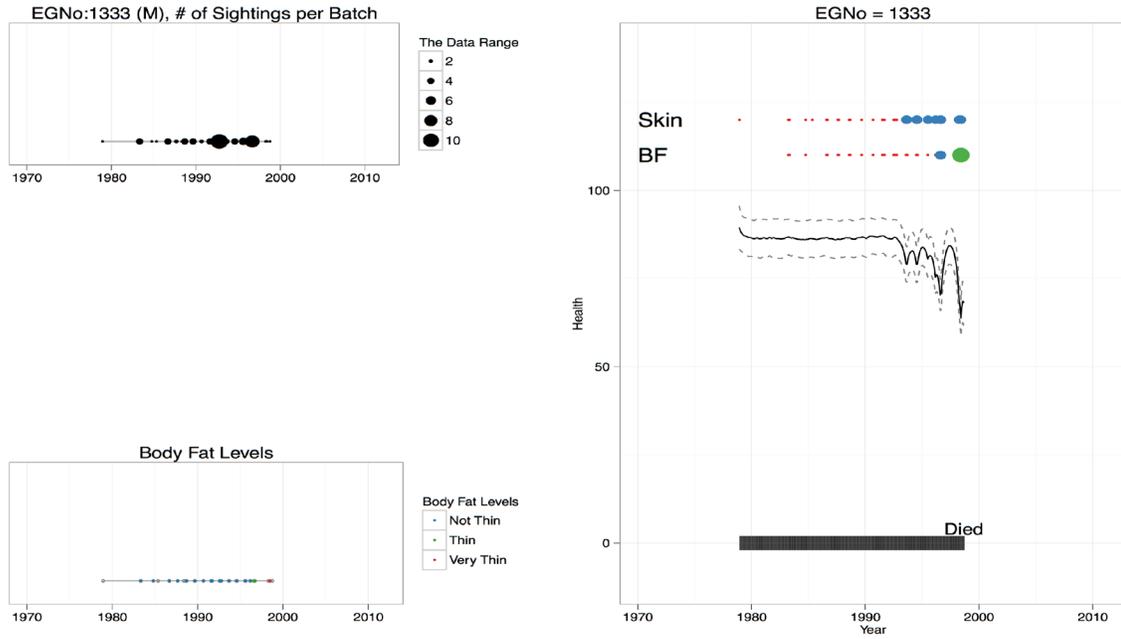


Figure 3. Left panel depicts photographic observations of one individual (EGNo 1333). Right panel depicts estimates of health with uncertainty for this same whale over time. This whale has died, and the estimates of health leading up to the mortality are both declining and precise. Note that poor skin condition (larger blue dots) precede poor body fat condition (blue and then green dots).

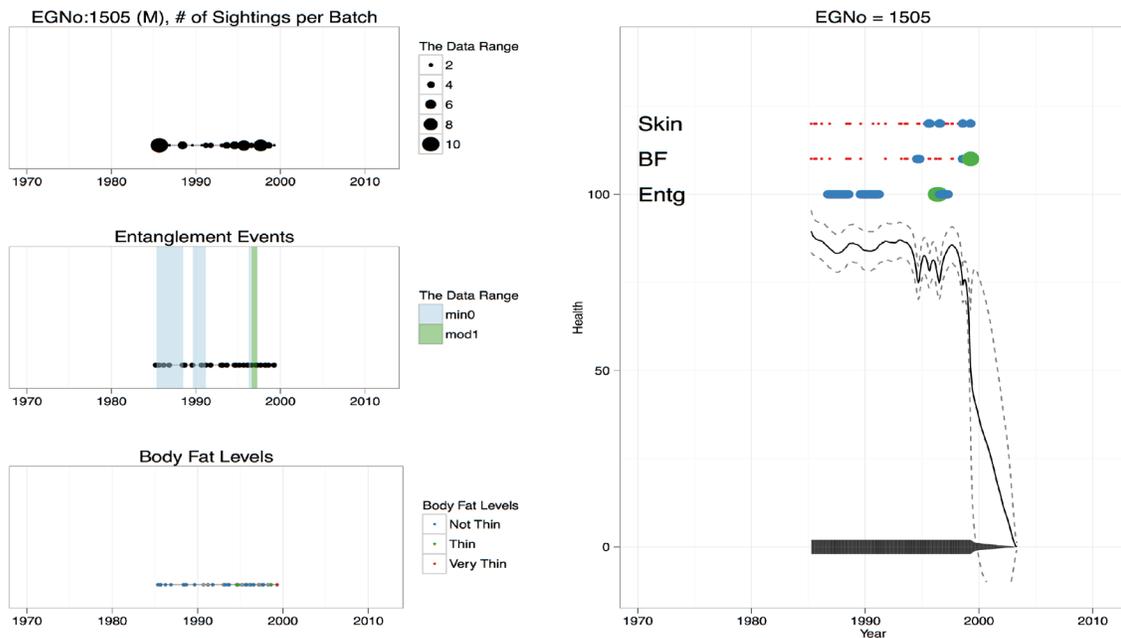


Figure 4. Left panel depicts photographic observations of one individual (EGNo 1505), an individual that has experienced 4 different entanglements. Right panel depicts estimates of health with uncertainty for this same animal over time. In contrast to Figure 1, this whale is presumed dead and the health trajectory is much less certain than a whale that is known to be dead.

IMPACT/APPLICATIONS

Despite continuous protection, studies, and monitoring, the population of North Atlantic right whales has been critically endangered for decades (Kraus et al. 2005). Previous population forecasts have been ominous (Caswell et al. 1999, Fujiwara & Caswell, 2001), and several dips in vital rates of the population have been documented in the past 20 years (Kraus & Rolland, 2007).

Since we can make observations of the health of individuals at different points in time (Pettis et al. 2004), the next step in the analysis is to incorporate most of the other data on right whales. The analysis undertaken here may be able to provide a comprehensive and quantitative understanding of the many factors that impact the health of North Atlantic right whales. This approach can help identify those anthropogenic or natural stressors which most affect mortality and/or reproduction, a critical need as different management scenarios and/or interventions are considered for this population.

Lastly, while this analysis and model is targeted to right whales, photographic observations of condition have been used to evaluate health in many other cetaceans (see, for example, Bradford et al. 2012). Therefore, it is feasible to extend this model to other well studied species. By using photographic observations of health and anthropogenic impacts together with this modeling approach, we can evaluate how the condition of whales varies over time and space and in response to specific extrinsic factors. This will increase our knowledge of the foraging ecology of marine mammals, and provide critical insight into risk factors for both individual whales and their populations.

RELATED PROJECTS

The New England Aquarium's Ocean Health and Marine Stress Programs include studies of stress in beaked and sperm whales (R. Rolland, PI; ONR # N000141110540), and a study on the detection and use of hormones from right whale respiratory exudate (K. Hunt, PI; ONR # N000141110435).

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